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EFFECTS OF VERTICAL WIND ON TACTICAL
ROCKETS AND ARTILLERY SHELLS

Bernard F. Engebos

Army Electronics Command
White Sands Missile Range, New Mexico

November 1972

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I. C

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CONTENTS

	Page
INTRODUCTION	1
DISCUSSION	1
THE HONEST JOHN (M50) TACTICAL ROCKET	2
THE 155 MILLIMETER HOWITZER PROJECTILE	2
CONCLUSIONS	6
LITERATURE CITED	7
 FIGURE 1. HONEST JOHN BALLISTIC FACTOR CURVES	 4
FIGURE 2. 155 HOWITZER BALLISTIC FACTOR CURVES	5
 TABLE 1. TABULATION OF UNIT WIND EFFECTS	 3

INTRODUCTION

In the computation of launcher angle settings for tactical rockets and/or artillery shells, one usually considers the rotation of the earth, the muzzle velocity, the horizontal wind components, the air temperature, the air density, the height of the target with respect to the launch point, the height of the launcher above sea level, and the weight of the projectile to be fired [1]. At present there is no launcher setting compensation for the vertical wind component.

This report examines the effects of the vertical wind component on projectiles and tactical rockets, and points out the possible consequences of neglecting this parameter. To accomplish this end, the Honest John (M50) tactical rocket and the 155 millimeter howitzer were selected as typical weapons. Other weapons yield similar results. All results in this report are accomplished by trajectory simulations and assume sea level as both launch and impact elevation.

DISCUSSION

The Honest John (M50) tactical rocket with the "heavy" warhead configuration is a single-stage unguided rocket with a 3.5 second burning phase. All trajectory simulations for this rocket are based on the equations of motion as developed in [2]. Quadrant elevation (QE) angles of 200, 400, and 800 mils were analyzed. These resulted in nominal (no wind) impact ranges of 13.6, 23.0, and 33.0 kilometers, and apogees of 650, 2800, and 10200 meters, respectively.

The 155 millimeter howitzer projectile, HD, M107, Fuze, PD, M51A5, charge 5C, was selected as a representative artillery projectile. The same quadrant elevation angle cases as above were analyzed. These resulted in nominal impact ranges of 4.4, 7.5, and 11.0 kilometers, and peak altitudes of 240, 865, and 2800 meters, respectively.

All the simulations on this projectile are based on the equations of motion as developed in [3] with the appropriate modifications to include the Magnus force [4]. Corresponding results were obtained using the Ballistic Research Laboratory Modified Point Mass model [5] with the introduction of vertical winds.

The wind response characteristics of an unguided rocket and/or an artillery shell are usually displayed in the form of the wind weighting factors and the unit wind effects (i.e., magnitude of the vector difference a unit wind change causes on the impact point). The determination of the wind weighting factors, which are usually displayed in the form of a cumulative response curve, follows the procedure as defined in [6]. The wind weighting (ballistic) factor curve usually indicates the percentage of total wind displacement from a no-wind impact yielded by a constant wind to a given altitude and zero wind thereafter.

The vertical wind field can be induced either by thermal or mechanical means. Over a relatively flat terrain, vertical winds, resulting primarily from the convective heating of the Earth's surface, are relatively small in magnitude and tend to fluctuate in speed and direction with respect to both time and distance down range. The vertical winds, mechanically induced by a hill or an obstacle, seem to maintain their direction for longer durations of time and are usually greater in magnitude than thermally induced vertical winds.

THE HONEST JOHN (M50) TACTICAL ROCKET

A plot of the cumulative response curve for the Honest John (M50) tactical rocket with quadrant elevation angles of 200, 400, and 800 mils is shown in Figure 1. The cocking of the rocket into the wind during the burning phase and the subsequent drifting of the rocket with wind during the coasting phase cause the derivative of the response curve to go negative after burnout. It should be noted that most of the wind response occurs below 300 meters MSL.

The unit wind effects for the Honest John rocket are displayed in Table 1. The vertical unit wind effect is a function of both the magnitude and direction of the vertical wind component. It should be noted that for an elevation angle of 200 mils, the vertical unit wind effect is four to five times larger than its horizontal counterpart. Thus it is quite possible for the vertical wind displacement of the rocket to be of the same magnitude as that caused by the horizontal component. In fact, for a QE of 200 mils, a range displacement of up to 300 meters can result from a reasonable vertical wind component, i.e., vertical wind speeds up to 2 miles per hour. It should be noted, however, that the M50 rocket is normally fired at higher QE's. The 300 meter displacement was derived from estimates of the vertical wind magnitude obtained at White Sands Missile Range, New Mexico [7]. This is significant since the one range probable error for 200 mils is 260 meters.

THE 155 MILLIMETER HOWITZER PROJECTILE

The 155 millimeter howitzer projectile, HD, M107, Fuze, PD, M51A5, charge 5G, has a muzzle velocity of 375 meters per second and a spin rate of 766 radians per second. This high spin rate is used for flight path stability. The maximum range of this projectile corresponds to an elevation angle near 800 mils. Thus, in general it is possible to achieve a desired impact range with either a high or low (more or less than 800 mils) elevation angle. A low QE angle is the usual mode of operation. High quadrant elevation angles are used for defilade fire to lob a projectile over a hill or some other obstacle, and are used sparingly.

TABLE I
TABULATION OF UNIT WIND EFFECTS

QUADRANT ELEVATION (MILS)		UNIT WIND EFFECTS (METERS/MPH)			
		CROSS	HEAD	TAIL	VERTICAL*
M50 ROCKET	200	62.4	61.3	60.6	276.5-332.6
	400	102.0	87.2	87.9	124.2-140.3
	800	185.7	108.5	105.1	7.4-19.7
155 HOWITZER	200	2.2	9.4	9.4	10.3-10.7
	400	5.4	21.5	21.5	14.8-15.2
	800	11.2	30.0	29.8	22.8-23.5

*The magnitude of the vertical unit wind effect is a function of both the direction (up or down) and the magnitude of the wind speed.

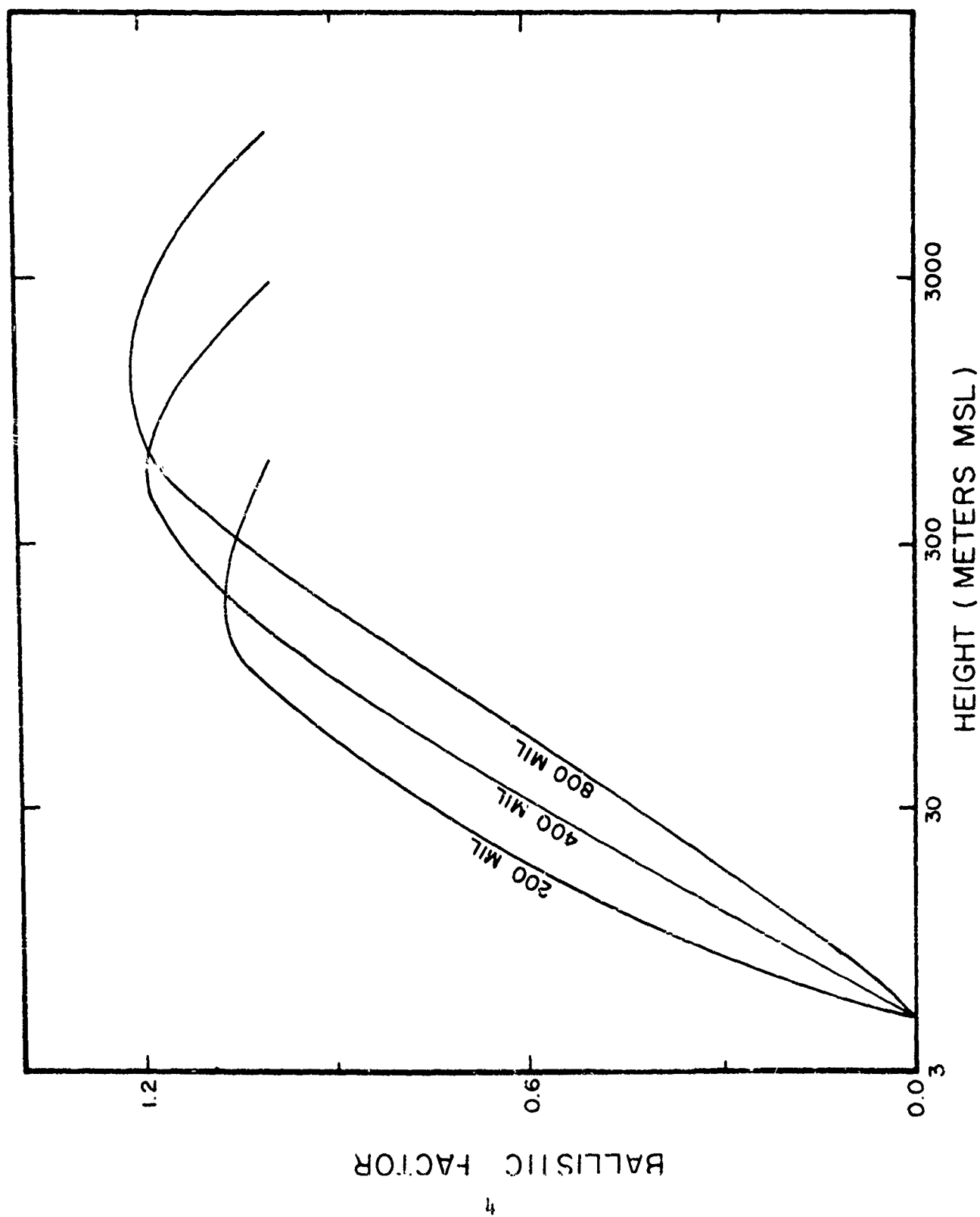


FIGURE 1. HONEST JOHN BALLISTIC FACTOR CURVES

One should note from a plot of the cumulative response curve for the 155 howitzer (see Figure 2) that most of the wind response for the projectile occurs near the apogee of the trajectory.

The unit wind effects for the 155 howitzer are displayed in Table I. For each of the quadrant elevation angles, the magnitude of the vertical unit wind effect is approximately equal to that of the range component of the horizontal wind. Hence, for a low QE, good impact accuracy is generally possible even when neglecting any vertical wind compensated launcher setting. This is due to the relatively small magnitude of the vertical wind component in comparison to that of the horizontal component. However, during thunderstorm activity, large vertical wind currents can be present. If the projectile is to be lobbed over a hill or some obstacle where the vertical wind component can be as large as 20 meters per second [8], or if it is to be fired during thunderstorm activity, large impact errors can result from the neglect of the vertical wind component.

CONCLUSIONS

The vertical wind component plays a significant role on the impact point of both a M50 rocket fired at a low elevation angle and a 155 howitzer projectile fired at a high elevation angle, although this is not the usual mode of operation. Also during thunderstorm activities, the vertical wind effect on the 155 howitzer can and usually will be significant for any elevation angle. To obtain best accuracy for these cases, one must include launcher setting corrections to compensate for the vertical wind effects. At the present, no such compensation is made. Much should be done in this area. An analysis of the vertical wind field with respect to time and distance down range of the launch site, an estimate of the vertical wind the rocket is expected to encounter, and a method to implement the necessary corrections to the launcher settings are areas of possible research to help alleviate this problem.

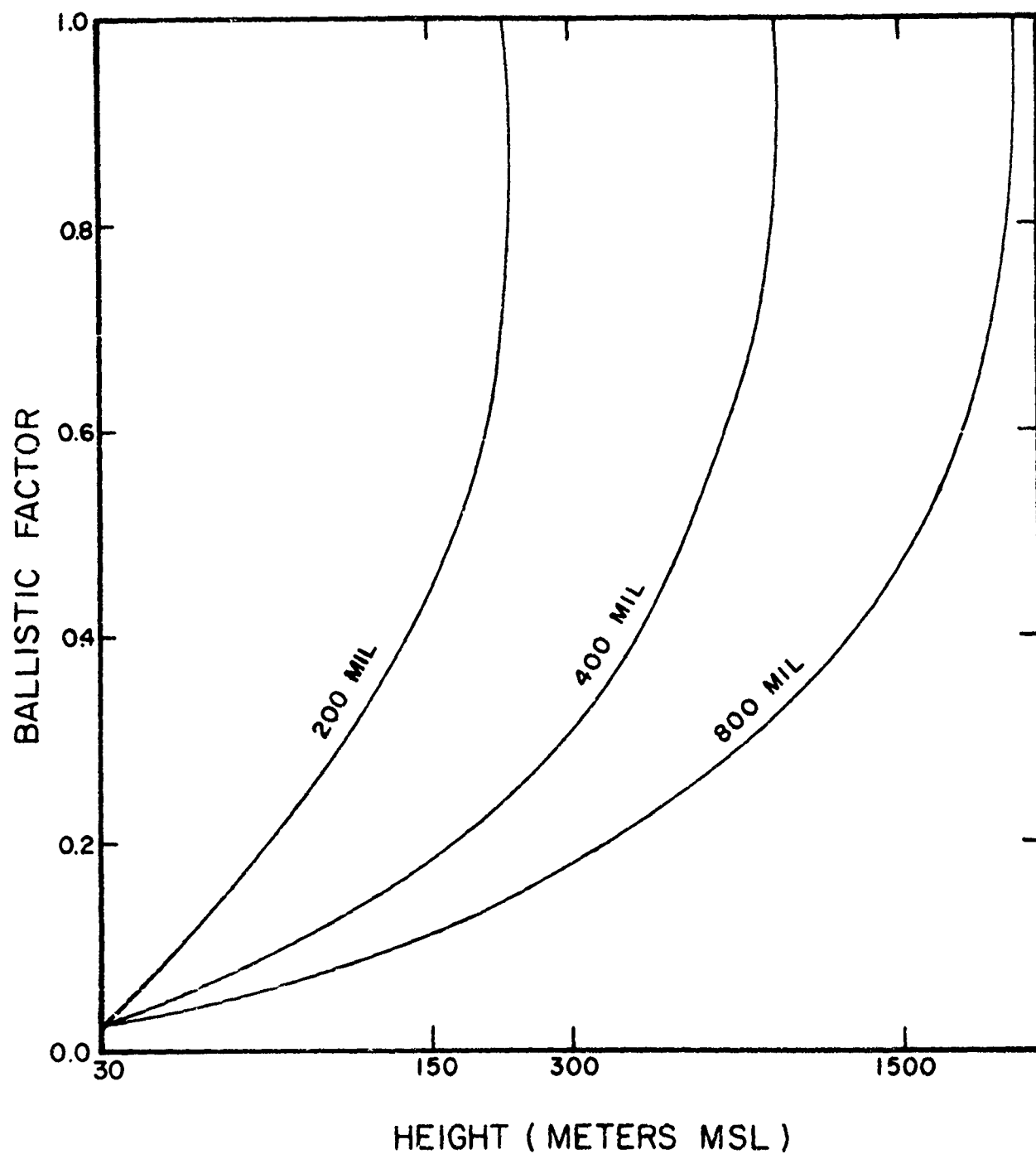


FIGURE 2. 155 HOWITZER BALLISTIC FACTOR CURVES

LITERATURE CITED

1. Firing Tables, FTR, 762-HI, Headquarters, Department of the Army, p. 16 (1963).
2. Walter, Dr. Everett L., 1962, "Six-Variable Ballistic Model for a Rocket," MM445, US Army Signal Missile Support Agency, White Sands Missile Range, New Mexico.
3. Duncan, L. D., and R. J. Ensey, 1964, "Six Degree of Freedom Digital Simulation Model for Unguided Fin-Stabilized Rockets," ERDA-196, US Army Electronics Research and Development Activity, White Sands Missile Range, New Mexico.
4. Nicolaides, Dr. John D., Free Flight Dynamics, Department of Aerospace Engineering, University of Notre Dame, Notre Dame, Indiana (unpublished).
5. Lieske, Robert F., and M. L. Reiter, 1966, "Equations of Motion for Modified Point Mass Trajectory," Ballistic Research Laboratory Report No. 1314, Aberdeen Proving Ground, Maryland.
6. Duncan, L. D., and B. F. Engebos, 1970, "A Rapidly Converging Iterative Technique for Computing Wind Compensation Launcher Settings for Unguided Rockets," ARO-D-Report 70-1, Transactions of the Fifteenth Conference of Army Mathematicians.
7. Rider, Laurence, and M. Armendariz, 1969, "Vertical Wind Component Estimates Up To 1.2 km Above Ground," ECOM-5258, Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico.
8. Alaka, M. A., ed., 1960, The Airflow Over Mountains, Note No. 34, World Meteorological Organization, Geneva.

ATMOSPHERIC SCIENCES RESEARCH PAPERS

1. Miers, B. T., and J. E. Morris, Mesospheric Winds Over Ascension Island in January, July 1970, ECOM-5312, AD 711851.
2. Webb, W. L., Electrical Structure of the D- and E-Region, July 1970, ECOM-5313, AD 714365.
3. Campbell, G. S., F. V. Hanscn and R. A. Dise, Turbulence Data Derived from Measurements on the 32-Meter Tower Facility, White Sands Missile Range, New Mexico, July 1970, ECOM-5314, AD 711852.
4. Pries, T. H., Strong Surface Wind Gusts at Holloman AFB (March-May), July 1970, ECOM-5315, AD 711853.
5. D'Arcy, E. M., and B. F. Engebos, Wind Effects on Unguided Rockets Fired Near Maximum Range, July 1970, ECOM-5317, AD 711854.
6. Matonis, K., Evaluation of Tower Antenna Pedestal for Weather Radar Set AN/TPS-41, July 1970, ECOM-3317, AD 711520.
7. Monahan, H. H., and M. Armendariz, Gust Factor Variations with Height and Atmospheric Stability, August 1970, ECOM-5320, AD 711855.
8. Stenmark, E. B., and L. D. Drury, Micrometeorological Field Data from Davis, California; 1966-67 Runs Under Non-Advection Conditions, August 1970, ECOM-6051, AD 726390.
9. Stenmark, E. B., and L. D. Drury, Micrometeorological Field Data from Davis, California; 1966-67 Runs Under Advection Conditions, August 1970, ECOM-6052, AD 724612.
10. Stenmark, E. B., and L. D. Drury, Micrometeorological Field Data from Davis, California; 1967 Cooperative Field Experiment Runs, August 1970, ECOM-6053, AD 724613.
11. Rider, L. J., and M. Armendariz, Nocturnal Maximum Winds in the Planetary Boundary Layer at WSMR, August 1970, ECOM-5321, AD 712325.
12. Hansen, F. V., A Technique for Determining Vertical Gradients of Wind and Temperature for the Surface Boundary Layer, August 1970, ECOM-5324, AD 714366.
13. Hansen, F. V., An Examination of the Exponential Power Law in the Surf. ~ Boundary Layer, September 1970, ECOM-5326, AD 715349.
14. Miller, W. B., A. J. Blanco and L. E. Traylor, Impact Deflection Estimators from Single Wind Measurements, September 1970, ECOM-5328, AD 716993.
15. Duncan, L. D., and R. K. Walters, Editing Radiosonde Angular Data, September 1970, ECOM-5330, AD 715351.
16. Duncan, L. D., and W. J. Vechione, Vacuum Tube Launchers and Boosters, September 1970, ECOM-5331, AD 715350.
17. Stenmark, E. B., A Computer Method for Retrieving Information on Articles, Reports and Presentations, September 1970, ECOM-6050, AD 724611.
18. Hudlow, M., Weather Radar Investigation on the BOMEX, September 1970, ECOM-3329, AD 714191.
19. Combs, A., Analysis of Low-Level Winds Over Vietnam, September 1970, ECOM-5346, AD 876935.
20. Rinehart, G. S., Humidity Generating Apparatus and Microscope Chamber for Use with Flowing Gas Atmospheres, October 1970, ECOM-5332, AD 716994.
21. Miers, B. T., R. O. Olsen, and E. P. Avara, Short Time Period Atmospheric Density Variations and a Determination of Density Errors from Selected Rocket-sonde Sensors, October 1970, ECOM-5335.
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23. Lindberg, J. D., The Uncertainty Principle: A Limitation on Meteor Trail Radar Wind Measurements, October 1970, ECOM-5337, AD 716996.
24. Randhawa, J. S., Technical Data Package for Rocket-Borne Ozone-Temperature Sensor, October 1970, ECOM-5338, AD 716997.

25. Devine, J. C., The Fort Huachuca Climate Calendar, October 1970, ECOM-6054.
26. Allen, J. T., Meteorological Support to US Army RDT&E Activities, Fiscal Year 1970 Annual Report, November 1970, ECOM-6055.
27. Shinn, J. H., An Introduction to the Hyperbolic Diffusion Equation, November 1970, ECOM-5341, AD 718616.
28. Avara, E. P., and M. Kays., Some Aspects of the Harmonic Analysis of Irregularly Spaced Data, November 1970, ECOM-5344, AD 720198.
29. Fabrici, J., Inv. of Isotopic Emitter for Nuclear Barometer, November 1970, ECOM-3349, AD 876461.
30. Levine, J. R., Summer Mesoscale Wind Study in the Republic of Vietnam, December 1970, ECOM-3375, AD 721585.
31. Petriw, A., Directional Ion Anemometer, December 1970, ECOM-3379, AD 720573.
32. Randhawa, J. S., B. H. Williams, and M. D. Kays, Meteorological Influence of a Solar Eclipse on the Stratosphere, December 1970, ECOM-5345, AD 720199.
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34. Avara, E. P., The Analysis of Variance of Time Series Data Part I: One-Way Layout, January 1971, ECOM-5352, AD 721594.
35. Avara, E. P., The Analysis of Variance of Time Series Data Part II: Two-Way Layout, January 1971, ECOM-5353.
36. Avara, E. P., and M. Kays., The Effect of Interpolation of Data Upon the Harmonic Coefficients, January 1971, ECOM-5354, AD 721593.
37. Randhawa, J. S., Stratopause Diurnal Ozone Variation, January 1971, ECOM-5355, AD 721309.
38. Low, R. D. H., A Comprehensive Report on Nineteen Condensation Nuclei (Part II), January 1971, ECOM-5358.
39. Armendariz, M., L. J. Rider, G. Campbell, D. Favier and J. Serna, Turbulence Measurements from a T-Array of Sensors, February 1971, ECOM-5362, AD 726390.
40. Maynard, H., A Radix-2 Fourier Transform Program, February 1971, ECOM-5363, AD 726389.
41. Devine, J. C., Snowfalls at Fort Huachuca, Arizona, February 1971, ECOM-6056.
42. Devine, J. C., The Fort Huachuca, Arizona 15 Year Base Climate Calendar (1956-1970), February 1971, ECOM-6057.
43. Levine, J. R., Reduced Ceilings and Visibilities in Korea and Southeast Asia, March 1971, ECOM-3403, AD 722735.
44. Gerber, H., et al., Some Size Distribution Measurements of AgI Nuclei with an Aerosol Spectrometer, March 1971, ECOM-3414, AD 729331.
45. Engebos, B. F., and L. J. Rider, Vertical Wind Effects on the 2.75-inch Rocket, March 1971, ECOM-5365, AD 726321.
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68. Avara, E. P., and B. T. Miers, Noise Characteristics of Selected Wind and Temperature Data from 30-65 km, August 1971, ECOM-5402.
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77. Dickson, David H., and James R. Oden, Fog Dissipation Techniques for Emergency Use, January 1972, ECOM-5420.
78. Ballard, H. N., N. J. Beyers, B. T. Miers, M. Izquierdo, and J. Whitacre, Atmospheric Tidal Measurements at 50 km from a Constant-Altitude Balloon, December 1971, ECOM-5417.
79. Miller, Walter B., On Calculation of Dynamic Error Parameters for the Rawinsonde and Related Systems, January 1972, ECOM-5422.

80. Richter, Thomas J., Rawin Radar Targets, February 1972, ECOM-5424.
81. Pena, Ricardo, L. J. Rider, and Manuel Armendariz, Turbulence Characteristics at Heights of 1.5, 4.0, and 16.0 Meters at White Sands Missile Range, New Mexico, January 1972, ECOM-5421.
82. Blanco, Abel J., and L. E. Traylor, Statistical Prediction of Impact Displacement due to the Wind Effect on an Unguided Artillery Rocket During Powered Flight, March 1972, ECOM-5427.
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97. Bonner, R. S., and H. M. White, Microphysical Observations of Fog in Redwood Valley near Arcata-Eureka, California, July 1972, ECOM-5455.
98. Waite, R. W., Reliability Test of Electronics Module of Meteorological Measuring Set AN/TMQ-22(XE-4), June 1972, ECOM-5448.
99. Doswell, C. A., III, An Iterative Method for Saturation Adjustment, June 1972, ECOM-5444.
100. Doswell, C. A., III, A Two-Dimensional Short-Range Fog Forecast Model, May 1972, ECOM-5443.
101. Seagraves, Mary Ann B., A General-Purpose Meteorological Rocket Data Reduction Program, August 1972, ECOM-5463.
102. Loveland, R. B., J. L. Johnson, and B. D. Hinds, Differential Magnetic Measurements Near Cumulus Clouds, August 1972, ECOM-5463.
103. Cantor, Israel, and Michael Hudlow, Rainfall Effects on Satellite Communications in the K, X, and C Bands, July 1972, ECOM-5459.
104. Randhawa, J. S., Variations in Stratospheric Circulation and Ozone During Selected Periods, August 1972, ECOM-5460.
105. Rider, L. J., Armendariz, Manuel, Mean Horizontal Wind Speed and Direction Variability at Heights of 1.5 and 4.0 Meters Above Ground Level at WSMR, New Mexico, October 1972, ECOM-5466.

106. Nordquist, Walter S., Jr., and Dickson, David H., Helicopter Downwash Applied to Fog Clearing: A Status Summary, October 1972, ECOM-5465.
107. Engebos, Bernard F., Effects of Vertical Wind on Tactical Rockets and Artillery Shells, November 1972, ECOM-5467.